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3

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TITLE DAMAGE TO FUSED SILICA WINDOWS WHILE UNDER SIMULTANEOUS EXPOSURE TO FLOWING SOLVENTS AND LASER RADIATION AND 308nm

AUTHOR(S) Billie R. Mauro, CLS-6
Stephen R. Foltyn, CLS-6
Virgil E. Sanders, CLS-6

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MASTER

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Damage to Fused Silica Windows while under Simultaneous Exposure to Flowing Solvents and Laser Radiation at 308nm

Billie R. Mauro, Stephen R. Foltyn and Virgil Sanders

Los Alamos National Laboratory
Los Alamos, NM 87545

This paper reports the results of a study to determine the degrading effects of flowing dye solvents on the laser damage threshold of fused-silica windows at 308nm. Thresholds were measured at the SiO_2/solvent interface in a test cell. Bare SiO_2 tested in air at 308nm (20ns) typically exhibits a threshold ranging from 4 to 10 J/cm^2; with the solvent cyclohexane in contact, a threshold as low as 0.3 J/cm^2 was measured. The damage data indicate that window lifetime (number of shots) is independent of fluence at higher levels, and asymptotically approaches infinity at levels near threshold. Dielectric coatings were tested as possible damage-resistant barriers between the solvent and SiO_2; the results show some improvement in damage threshold. When cyclohexane is replaced with the solvent dioxane, thresholds measured for SiO_2 windows are within the range cited above for thresholds measured in air.

Key words: cyclohexane; dioxane; dye solvents; fused silica; optical damage; simultaneous exposure; window lifetime

1. Introduction

This study was undertaken in order to investigate the cause of damage to fused silica windows on preamplifier and oscillator cells in a large [illegible] pumped dye-laser system that contained the dye solvent cyclohexane. It was observed that damage in the system always first appeared as the deposition of a brown or carbon [illegible] on the inside faces of both the pump and output windows of the cells. These deposits [illegible] absorb laser light and lead to catastrophic failure of the window surfaces at fluence levels far lower than the damage threshold for the same window material tested in air.

2. Test Conditions

The laser used in this study is a Lambda Physik excimer laser, model EMG203, operating at 308nm with a pulse duration of 20 ns. Figure 1 illustrates the experimental layout of the laser damage test facility. The experimental set up incorporates a flow simulator with replaceable test windows (shown in Fig. 2). Normal test conditions include a solvent flow rate of four gallons per minute, a clearing ratio of [illegible], a laser spot size of 1mm x 12mm, and a pulse repetition rate of 20 Hz. The test plane is located at the SiO_2/solvent interface of the test cell. While the cell window is simultaneously exposed to flowing solvent and laser radiation, damage is observed visually with a telescope and video camera. The damage threshold is determined to be the highest test plane fluence at which no damage [illegible] [illegible] [illegible]

3. Test Results

3.1. Cyclohexane Data

Experimental results for near-uv dye lasers pumped with pulses from a XeCl laser have shown that the solvent will effect the operation of a dye laser -- particularly its photochemical stability [1]. Therefore, initial tests for this experiment utilized the solvent cyclohexane alone: no laser dye was added to the solvent. Damage, appearing as the deposition of carbon or carbon compounds, was produced at fluence levels as low as 0.4 J/cm^2; yet thresholds for bare SiO_2 tested in air at this facility range from 4 to 10 J/cm^2 and carbon deposits are not a part of the damage morphology. The fused-silica damage data for cyclohexane (fig. 3) indicate asymptotic behavior at threshold and, at fluences above threshold, all damage is delayed and occurs at approximately 10^5 shots. Tests at varied pulse-repetition rates (100 to 200 Hz), solvent-flow rates (2 to 4 gpm), and clearing ratios (1 to 3) reveal no significant dependence of damage on any of these parameters.

In an attempt to improve on the window damage threshold when in contact with cyclohexane, two other window materials were tested. Sapphire windows exhibit threshold behavior at 1.3 J/cm^2 and the damage also appears as carbon deposits. Sapphire windows tested in air at this facility produced a damage threshold of 2 J/cm^2. A MgF_2 window could not be damaged in 10^6 shots at up to 3.3 J/cm^2, which was the maximum test-plane fluence attainable with the 1 x 12mm beam. However, previous tests of MgF_2 in air at 248nm and 351nm have produced thresholds of 19 and 20 J/cm^2, respectively [2]. Dielectric coatings were tested as possible damage-resistant barriers between the solvent and SiO_2. As seen in the following table, thicker coatings (10,000 Å) can improve damage threshold nearly 1.5 times while thinner coatings provide little or no improvement. These combined results imply that the window is not simply a passive surface that collects the products of photo-dissociation, but is an active participant in the reactions.

Table 1. Coatings as Barriers between SiO_2 and Cyclohexane

Materials Tested	Damage Threshold (J/cm^2)
Al_2O_3 single layer (10,000 Å) on SiO_2	1.9
Al_2O_3 antireflector (~1,000 Å) on SiO_2	1.1
Al_2O_3 single layer (100 Å) on SiO_2	0.8
uncoated SiO_2 companion sample	0.8

3.2. Dioxane Data

A major improvement in damage threshold occurs when the solvent dioxane is used. As seen in figure 4, the thresholds exceed those measured in cyclohexane by an order of magnitude. (It was necessary to damage threshold could not be attributed to a decreased spot size.) Further, no carbon deposits were observed on the cell windows -- damage appears to be a surface-roughening process similar to that seen on samples tested in air. Although companion samples tested in air and in dioxane produce nearly the same damage thresholds (8 to 10 J/cm^2), those tested in dioxane appear to produce delayed damage. (This might be attributed to a partial index match between the dioxane and SiO_2 which could make damage more difficult to see.)

4. Conclusions

The data for SiO_2 windows tested in cyclohexane suggest that damage is independent of repetition rate or flow conditions. Further, damage near threshold occurs after an accumulation of shots depending on fluence, while at values above threshold, damage occurs after a fixed number of shots regardless of test-plane fluence. A thick dielectric coating is able to protect the SiO_2 surface at test-plane fluences up to nearly 1.5 times the damage threshold for uncoated SiO_2, while thinner coatings show little or no improvement. Finally, the data suggest that cyclohexane damage is a photochemical process rather than a photodeposition process, and the photochemical process is more pronounced for SiO_2 windows than for Al_2O_3 or MgF_2 windows.

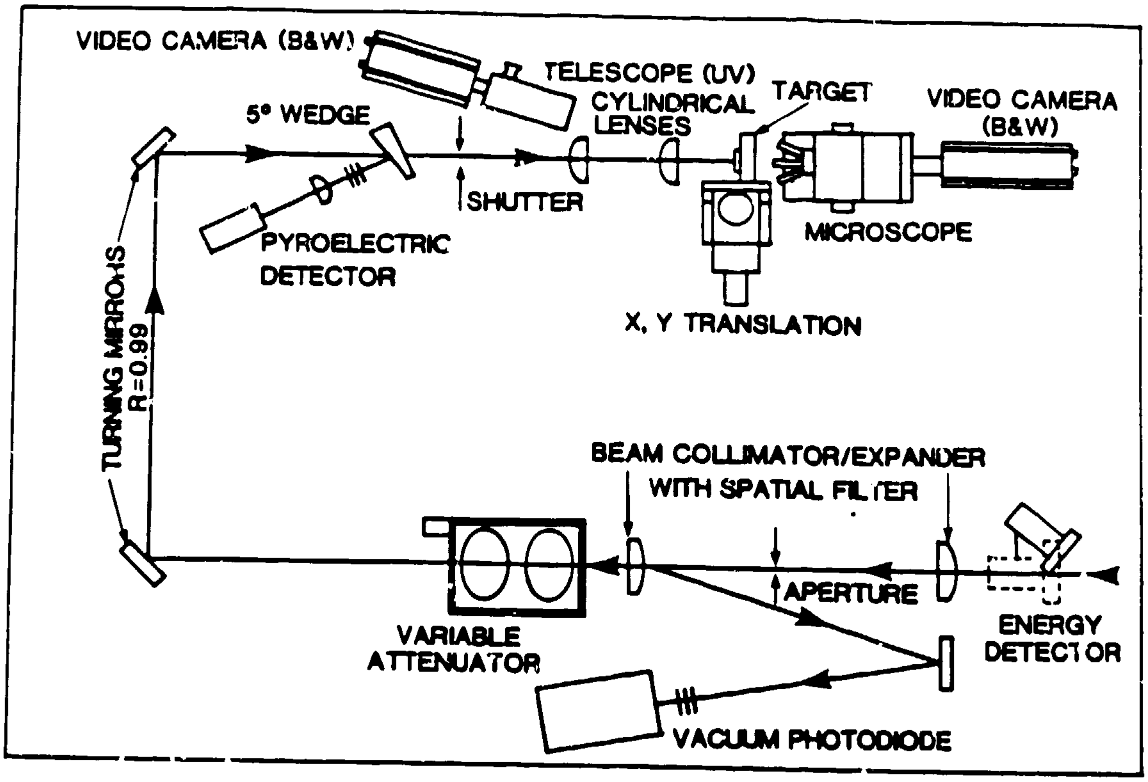
For tests in the solvent dioxane, no photochemical deposition is observed in the damage mechanism. Fused-silica damage thresholds depend upon test-plane fluence, and, while damage appears to be delayed, thresholds are comparable to those measured for SiO_2 windows tested in air.

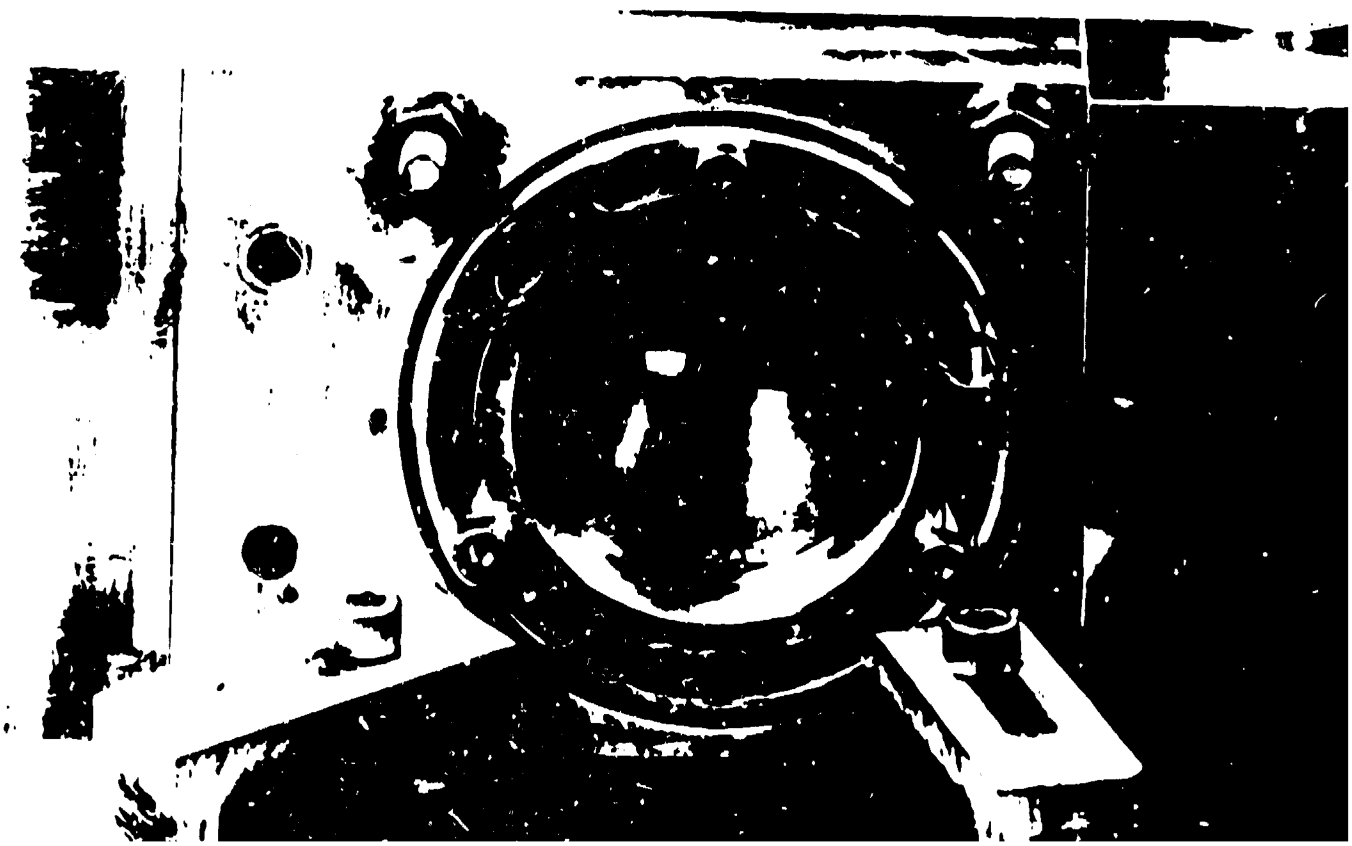
5. References

[1] [illegible], R. [illegible]orkum, A. J. Alcock, "Characteristics of XeCl pumped u.v. dye lasers," Appl. Phys. 25, 17-22 (1981).

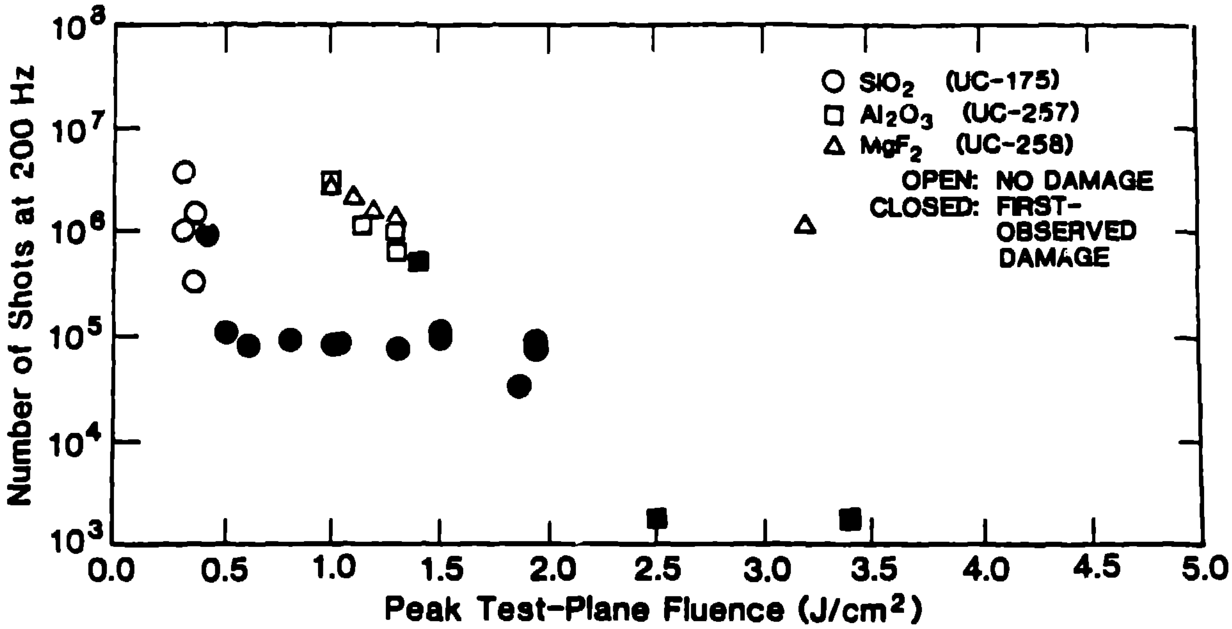
[2] L. J. Jolin, Los Alamos National Laboratory (unpublished test results).

XeCl Laser Damage Test Facility





Simultaneous Exposure of Windows to Flowing Cyclohexane and Laser Radiation at 308 nm



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Simultaneous Exposure of SiO_2 Windows to Flowing Dioxane and Laser Radiation at 308 nm